United States Environmental Protection Agency
Washington, DC 20460

# Work Assignment

Work Assignment Number: 1-48
● Original
○ Amendment

| Contract Number: EP-C-09-027 | Contract Period<br>Base:<br>Option Period No. 1 | SF Site Name: |
|---|---|---|

Title of Work Assignment: Solid-fuel Cook Stove Testing

| Suggested Source: ARCADIS | Specify Section & Paragraph of Contract SOW: Section 2.0 Laboratory Research, Para. 1-6. |
|---|---|
| Purpose:<br>● Work Assignment Initiation ○ Work Assignment Close-Out<br>○ Work Assignment Amendment ○ Incremental Funding<br>○ Work Plan Approval | Period of Performance<br>From: 04/01/2010 To: 05/31/2011 |
| Comments: Continuation of previous work assignment, Arcadis ContractEP-C-09-027, Base Period, WA Number 0-48. | QA Category (check one)<br>○ I Enforcement<br>○ II Standard Setting<br>○ III Technology Development<br>● IV Proof of Concept<br>○ N/A |

*Note: To report additional accounting and appropriations data use EPA Form 1900-69A.*

SFO 22 (Max 2) ☐ Superfund ☒ Non-Superfund

## Accounting and Appropriations Data

| | DCN (Max 6) | Budget/FYs (Max 4) | Appropriation Code (Max 6) | Budget Org/Code (Max 7) | Program Element (Max 9) | Object Class (Max 4) | Amount | Sites/Project (Max 8) | Cost Org/Code (Max 7) |
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## Authorized Work Assignment Ceiling

| Contract Period: | Cost/Fee | LOE |
|---|---|---|
| Previously Approved | New | 0 |
| This Action | | 0 |
| Total | | 0 |

## Work Plan / Cost Estimate Approvals

| | | |
|---|---|---|
| Contractor WP Dated: | Cost/Fee: | LOE: |
| Cumulative Approved: | Cost/Fee: | LOE: |

| | | | |
|---|---|---|---|
| Work Assignment Manager Name | Jim Jetter | Branch / Mail Code | IEMB / E305-03 |
| (Signature) | (Date) 2/25/2010 | Phone Number | (919) 541-4830 |
| | | Fax Number | 919-541-2157 |
| Branch Chief Name | Robert C. Thompson, Chief, IEMB | Branch/Mail Code | IEMB / E305-03 |
| (Signature) | (Date) 2/25/2010 | Phone Number | 919-541-1904 |
| | | Fax Number | 919-541-2157 |
| Project Officer Name | Diane Pierce | Branch/Mail Code | TSB / E343-03 |
| (Signature) | (Date) 3/11/10 | Phone Number | (919) 541-2708 |
| | | Fax Number | 919-541-0496 |
| Contracting Official Name | Renita Tyus, CO | Branch/Mail Code | CPOD |
| (Signature) | (Date) 3/15/10 | Phone Number | (513) 487-2094 |
| | | Fax Number | (513) 487-2109 |

Contractor Acknowledgement of Receipt and Approval of Workplan (Signature and Title) | Date

Work shall not begin on this work assignment until 04/01/10.

WA 1-48

# Statement of Work

## Solid-Fuel Cook Stoves Performance and Emissions Testing

### OBJECTIVES

The primary purpose of this study is to measure performance and pollutant emissions from practical, fuel-efficient, "clean-burning", solid-fuel stoves. Pollutant emissions from "clean-burning" stoves shall be compared to emissions from the traditional "three-stone" fire.

A second purpose of this study is to provide stove emissions information that will be valuable to EPA PCIA (Partnership for Clean Indoor Air) grantees and other partners that are disseminating stove technology in the field.

A third purpose of this study is to determine how solid-fuel cook stove performance and emissions are affected by the fuel moisture content.

### BACKGROUND

The Partnership for Clean Indoor Air was launched at the World Summit on Sustainable Development in Johannesburg in September 2002 to address the enormous environmental health risks faced by almost three billion people who burn traditional biomass fuels and coal indoors for cooking and heating. According to the World Health Organization, this widespread use results in the premature deaths of an estimated 1.6 million people each year from breathing elevated levels of indoor smoke, with women and children being most significantly affected. The EPA-led, voluntary Partnership brings together governments, public and private organizations, multilateral institutions, industry, and others to increase the use of affordable, reliable, clean, efficient, and safe home cooking and heating practices. For more information, see the PCIA web site at http://pciaonline.org

Solid-fuel cook stoves have recently gained more attention because of their emissions of black carbon, brown carbon, organic carbon, $CO_2$, and methane that affect global climate change.

Reducing problems associated with burning solid fuel indoors provides multiple benefits. Human health is improved through better indoor air quality and ambient air quality. Sustainability and ecology are promoted through reduced deforestation and protection of biodiversity. Global climate change is addressed through reduced greenhouse gas emissions. International relations are improved through collaboration with partners.

Stove testing, similar to this study, was previously performed by the on-site contractor under Contract No: EP-C-04-023, Work Assignments 2-36 and 3-36.

This work assignment is a continuation of work performed under Contract No. EP-C-09-027, Work Assignment 0-48, Solid-fuel Cook Stove Testing.

**TEST PLAN**

**Stoves to be tested:**
The EPA WAM will obtain the stoves to be tested. The Contractor shall operate the stoves during the testing.

**1. "Carefully tended" 3-stone fire.** The fire shall be constantly monitored and tended during the test. Fuel-wood sticks shall be slowly fed into the fire so that only the ends of the sticks burn. The fire shall be maintained so that the tips of the flames are approximately 1 to 4 cm beneath the pot. The fire shall be operated so most flames do not touch the pot, because flames that touch the pot are quenched and produce higher pollutant emissions.

**2. "Minimally tended" 3-stone fire.** The fire shall be constantly monitored, but shall be only periodically tended. Fuel-wood sticks shall be added in batches to the fire. Each batch of fuel-wood shall produce flames with a maximum height approximately the same height as the top of the pot. The fire shall be allowed to burn down with no tending until the flame tips are approximately 6 cm beneath the pot, then another batch of fuel wood shall be added to the fire to again bring the flames to a height approximately the same height as the top of the pot.

**3. Oorja First Energy Stove.** This stove is fueled with biomass pellets, and has forced draft (with a small electrical fan) for improved combustion. The stove was developed by BP (British Petroleum), and is now being disseminated by a small business, First Energy Private Limited. http://www.bioenergylists.org/node/2439

**4. StoveTec wood stove.** This "rocket" type, wood-burning stove is mass produced and has been widely disseminated in relatively large quantities. The stove has a ceramic combustion chamber, and an adjustable pot skirt that improves efficiency and reduces air pollutant emissions. http://www.stovetec.net/us/products/wood-stove

**5. Philips Model HD4010 fan stove.** Royal Philips Electronics of the Netherlands developed this stove with a cylindrical, stainless-steel combustion chamber, a small electric fan, a rechargeable battery, and a thermoelectric generator. The battery provides electrical power to the fan during start-up when the stove is cold, and the thermoelectric generator recharges the battery and powers the fan when the stove is hot. A relatively small amount of primary air is injected into the fuel in the bottom of the combustion chamber and a relatively large amount of secondary air is injected into the burning gases in the top of the combustion chamber. Air flow provided by the fan keeps the combustion chamber from overheating while the air is preheated before it is injected into the combustion chamber. During operation of the stove, small pieces of solid fuel are inserted between the top of the stove and the bottom of the pot. This stove was previously tested by EPA and was found to be the best performing stove (lowest emissions) among the stoves tested.

**6. EnviroFit Model G-3300 stove with G-33SKT pot skirt.** This "rocket" type, wood-burning stove is mass produced and has been widely disseminated in relatively large quantities. The stove has an alloy combustion chamber and an accessory, adjustable pot skirt that improves efficiency and reduces air pollutant emissions.
http://www.envirofit.org/?q=our-products/clean-cookstoves/technology/G-3300

**7. Beijing Linhong stove.** This is a "gasifier" type stove that has an electric fan and can use unprocessed corn cobs as fuel to replace coal consumption. This stove was one of the winners of the China stove competion. It is now being produced by the company Jinqilin in Shanxi, China.
http://www.vrac.iastate.edu/ethos/files/ethos2007/Sat_AM/Session_2/Charron%20Presentation%20for%20ETHOS%202007%20-China%20project%20(2).pdf

**8. LuciaStove for developing nations.** This stove, developed by the company WorldStove in Italy, is designed to burn small pieces of biomass fuel and to produce biochar. The company claims the stove produces a swirling flame pattern that improves heat transfer to the pot.
http://worldstove.com/products/luciastove-for-developing-nations/

**9. Berkeley-Darfur stove.** This stove, developed by Lawrence Berkeley National Laboratories for refugee camps in Darfur, is made of mass-produced metal components that can be efficiently shipped in flat packages and assembled near the point of use.
http://darfurstoves.org/

**10. "Unimproved" charcoal stove.** A charcoal stove that is representative of a more traditional "unimproved" design – to be decided.

**11. "Improved" charcoal stove.** A charcoal stove that is representative of an "improved" lower-emissions design – to be decided.

**Fuels to be tested:**
The EPA WAM will obtain the fuels to be tested.

Wood-burning stoves shall be tested with high- and low-moisture hardwood, white oak, fuel. A truck load (1/2 ton) of freshly cut "green" white oak firewood without bark, lengths approximately 14", will be obtained from a local vendor. The wood shall be cut on a table saw and/or band saw to produce sticks that shall be approximately 5/8" x 5/8" in cross section. Half of the fuel wood shall be air dried to a moisture content of approximately 10 percent (on a wet basis), and the other half of the fuel wood shall be stored in air-tight barrels to keep the moisture content as high as possible – expected to be approximately 25 percent.

The Philips fan stove and the LuciaStove shall be tested with the same fuel wood cut into lengths approximately 2".

The Oorja First Energy stove shall be tested with biomass fuel pellets supplied by the manufacturer. It shall be tested with the pellets "dry," as received, and shall be tested with pellets with added moisture – expected to be approximately 25 percent (on a wet basis).

The Beijing Linhong stove shall be tested with unprocessed corn cobs with high- and low-moisture content – to be determined.

The charcoal stoves shall be tested with "lump" charcoal (not compressed briquettes) similar to that available in developing countries. Stoves shall be tested with "dry" charcoal (approximately 5 percent moisture content on a wet basis) and charcoal with added moisture – expected to be about 15 percent. Charcoal shall be started with high-resin pine (also known as heart pine or "fatwood").

All fuels shall be analyzed for moisture content using ASTM Standard Method D4442-92. Moisture content of the fuels shall be measured on a daily basis. A random sample of fuel wood, with a mass of approximately 500 g, shall be weighed with an electronic balance. The sample shall be dried in a ventilated oven for at least 8 hours, and then the sample shall be weighed again. The percent moisture content in the wood on a percent wet basis shall be calculated and recorded.

All fuels shall be analyzed for heat of combustion using ASTM Standard Method ASTM D5865-04. This testing shall be done by a qualified outside laboratory.

**Total number of stove/fuel combinations to be tested:** 22

**Air pollutants to be measured:**
The contractor shall measure emissions of the following pollutants for each stove and fuel combination:

- $CO_2$ - real-time, CEM (IR)
- CO - real-time, CEM (IR)
- $PM_{2.5}$, measured gravimetrically, filter sample taken during each of the three phases of the WBT
- BC (black carbon) – quartz filter sample taken during each of the three phases of the WBT
- EC (elemental carbon) – quartz filter sample taken during each of the three phases of the WBT
- OC (organic carbon) – quartz filter sample taken during each of the three phases of the WBT
- PM, submicrometer particles measured with SMPS (scanning mobility particle sizer) (EPA WAM will provide instrument)
- THC (total hydrocarbon) - real time, FID total HC analyzer
- $CH_4$ (methane) - real time, FID analyzer
- Other pollutants may be added if resources (instruments and personnel) are available

The Contractor shall obtain the instrumentation and equipment necessary to measure air pollutants, in consultation with the EPA WAM.

BC/EC/OC analysis will be provided by EPA Emissions Characterization and Prevention Branch, contact: Michael Hays

**Test protocol:** WBT (Water Boiling Test) latest version. The WBT is currently being revised. The EPA WAM will provide a copy of the updated protocol, when it is available.

A summary of the most recent performance test protocol follows:

> "This modified version of the well-known Water Boiling Test (WBT) is a simulation of the cooking process that can be performed on most stoves in use throughout the world. While the test is not intended to replace other forms of stove assessment, it is designed to be a simple method by which stoves made in different places and for different cooking applications may be compared by a standardized and replicable protocol."
>
> "The WBT …consists of three phases.
> 1) In the first phase, the tester begins with the stove at room temperature and uses a pre-weighed bundle of wood to boil a measured quantity of water in a standard pot. The tester then replaces the boiled water with a fresh pot of cold water to perform the second phase of the test.
> 2) In the second phase, water is boiled beginning with a hot stove in order to identify differences in performance between a stove when it is cold and when it is hot.
> 3) Lastly, the tester again boils a measured amount of water and then, using a pre-weighed bundle of wood, simmers the water at just below boiling for a measured period of time (45 minutes). The third step simulates the long cooking of legumes or pulses that is common throughout much of the world."
>
> "This combination of tests is intended to measure the stove's performance at both high and low power outputs, which are important indicators of the stove's ability to conserve fuel."

**Facilities**

The contractor shall complete tests using the Open Burning Facility located in the OSA (Outside Storage Area) of the EPA campus in RTP, NC. The contractor shall set up an emissions collection hood and sampling duct system, in consultation with the EPA WAM.

**Results**

The contractor shall deliver data to the EPA WAM in a format, such as Excel, that can be easily processed. Results shall be reported as averages and standard deviations for the three tests for each stove. Following are results needed for each stove:

- Time to boil, cold start
- Mass of fuel used, cold start

- Pollutant emissions, cold start

- Time to boil, hot start
- Mass of fuel used, hot start
- Pollutant emissions, hot start

- Mass of fuel used, simmering
- Pollutant emissions, simmering

**Safety**

The Contractor shall comply with a Health and Safety Protocol. The Contractor shall maintain a safe working environment during testing.

**Quality Assurance**

The EPA work assignment manager will prepare a quality assurance project plan (QAPP) for this project. After preparation, the QAPP shall be reviewed and approved by the ARCADIS work assignment leader and QA officer. Once it has obtained their approval, it shall be submitted to the EPA QA staff for review and approval. It shall be accompanied by a signature page that is signed by the ARCADIS work assignment leader and QA officer to show that they have reviewed and approved the QAPP. It is the responsibility of the ARCADIS work assignment leader to document this process. Upon receipt of the signed QAPP, the EPA work assignment manager and QA manager will review and approve the QAPP and they will add their signatures to the signature page. Any work involving environmental data shall not commence until the QAPP has received official approval from the EPA QA staff.

**Reporting**

The Contractor shall prepare and deliver brief, monthly progress reports in accordance with the reporting requirements in the contract. The contractor shall deliver data and filter samples to the EPA WAM. The final report shall be prepared by the EPA WAM and shall be in the form of a manuscript to be submitted to a peer-reviewed journal for publication. Contractor personnel may be coauthors of the publication.

**Deliverables**

Test data and filter samples shall be deliverables.

Schedule is as follows:

| | |
|---|---|
| April 1, 2010 | Continue testing cook stoves (continuation of WA 0-48) |
| May 19, 2010 | Complete testing of cook stoves |
| May 31, 2010 | Deliver all test data and filter samples |